

The biology of mating



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Where is College Station, TX??



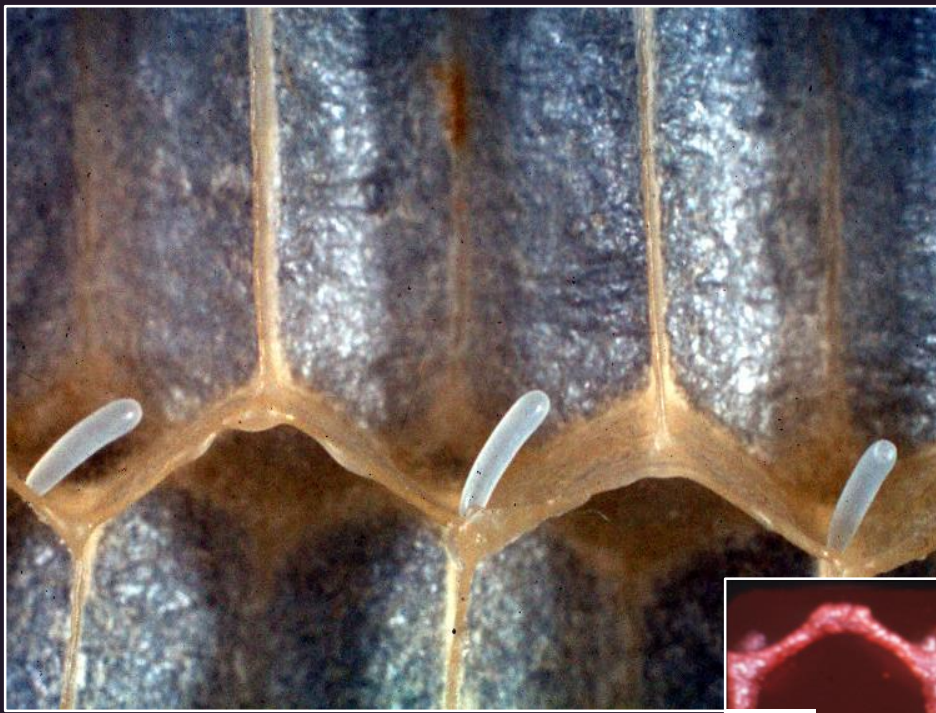
Biology of the queen



Honey bee queen biology

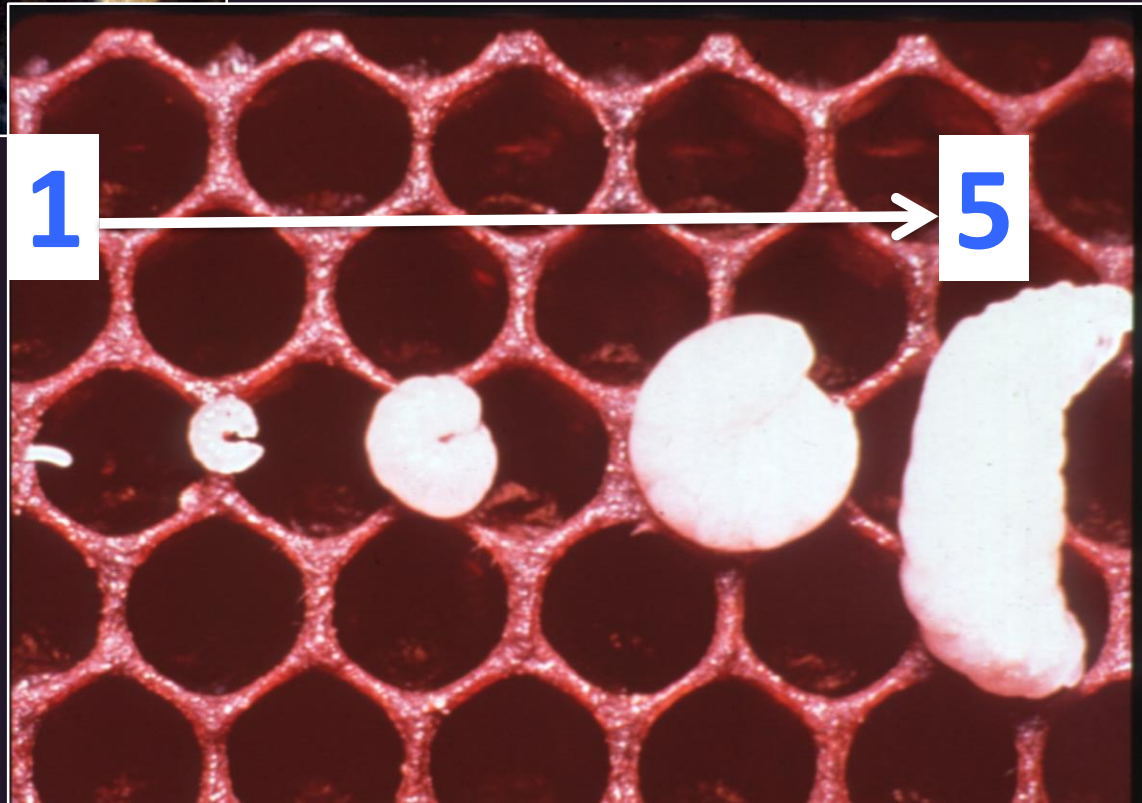
- A queen develops from a fertilized larva that is fed a special, proteinacious diet of “royal jelly”
- High levels of Royallactin, pantothenic acid, sugars, and high expression of *amTOR* gene
- The queen is the breeding depository of all the colony’s gene pool acquired from her parents and her mates

















Egg stage:
cellular
differentiation

Larval stage:
growth

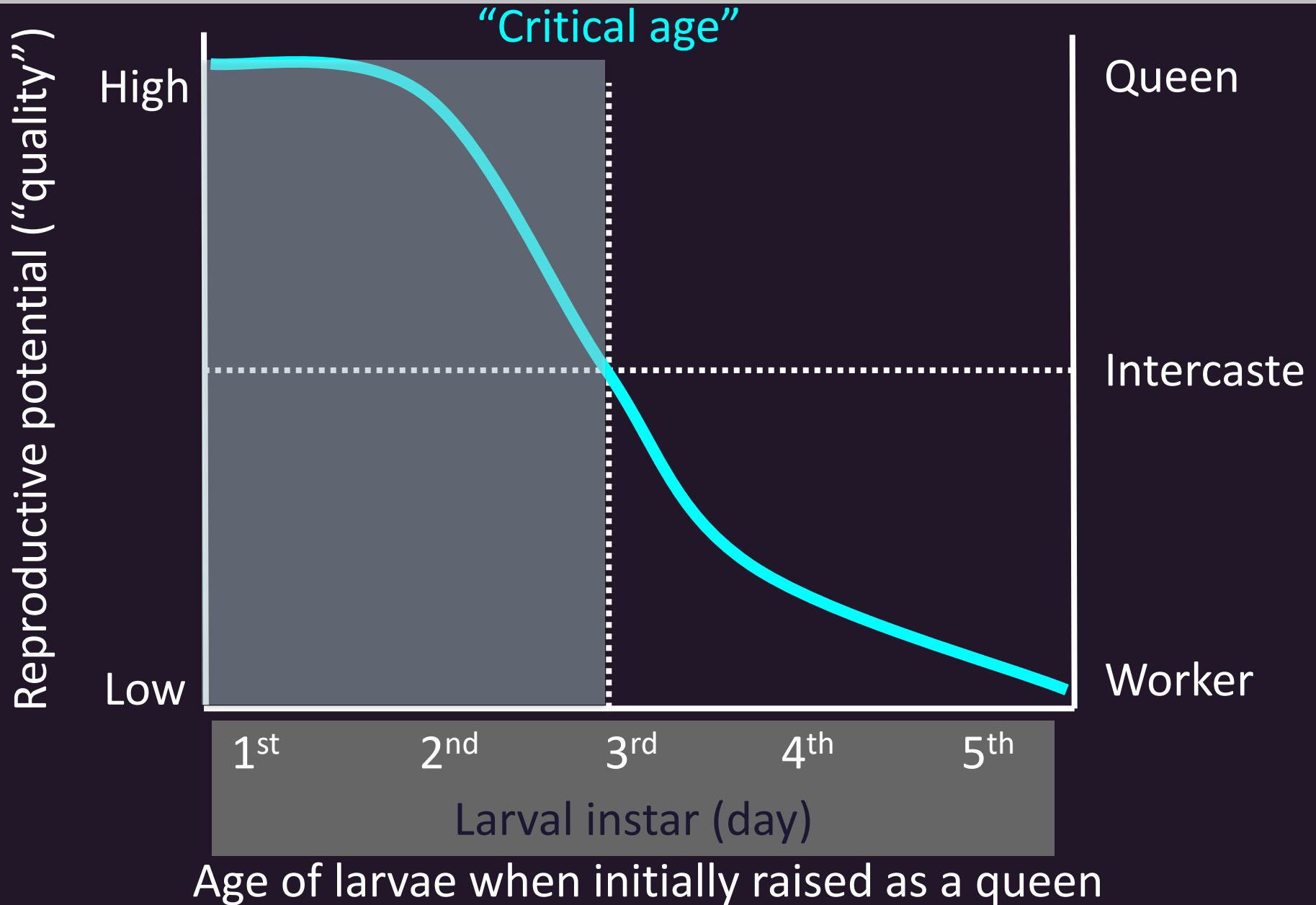


Honey bee queen development

- 16 days total from egg to queen emergence
- 3 days as egg
- 4th day – transition to larva
- Day 9 – larva is capped
- Day 16 – Queen emergence

Stages of growth:					
		EGG	LARVA	PUPA	ADULT BEE
QUEEN	Days 1-3		Days 4-9 	Days 10-15 	Day 16 
WORKER	Days 1-3		Days 4-9 	Days 10-20 	Day 21 
DRONE	Days 1-3		Days 4-9 	Days 10-23 	Day 24 

Variability in queen reproductive quality



Competition between emerging queens

- Queens do not emerge synchronously
- The first queen to emerge usually seeks out other developing queens and stings them to death



- If multiple queens emerge successfully, they will fight to the death
- The winner of these combats inherits the nest and is ready to mate

Check for queen emergence from cell

- Did the queen emerge from the cell properly?
- Look at the queen cell for proper emergence pattern:
 - Normal queen emergence
 - No queen emerge



Check for egg laying

- After emergence, the queen spends a couple of days roaming around the colony
- Seven days after emergence, the queen starts to take mating flights
- Ten days after emergence (and once properly mated) the queen starts laying eggs



Honey bee queen biology

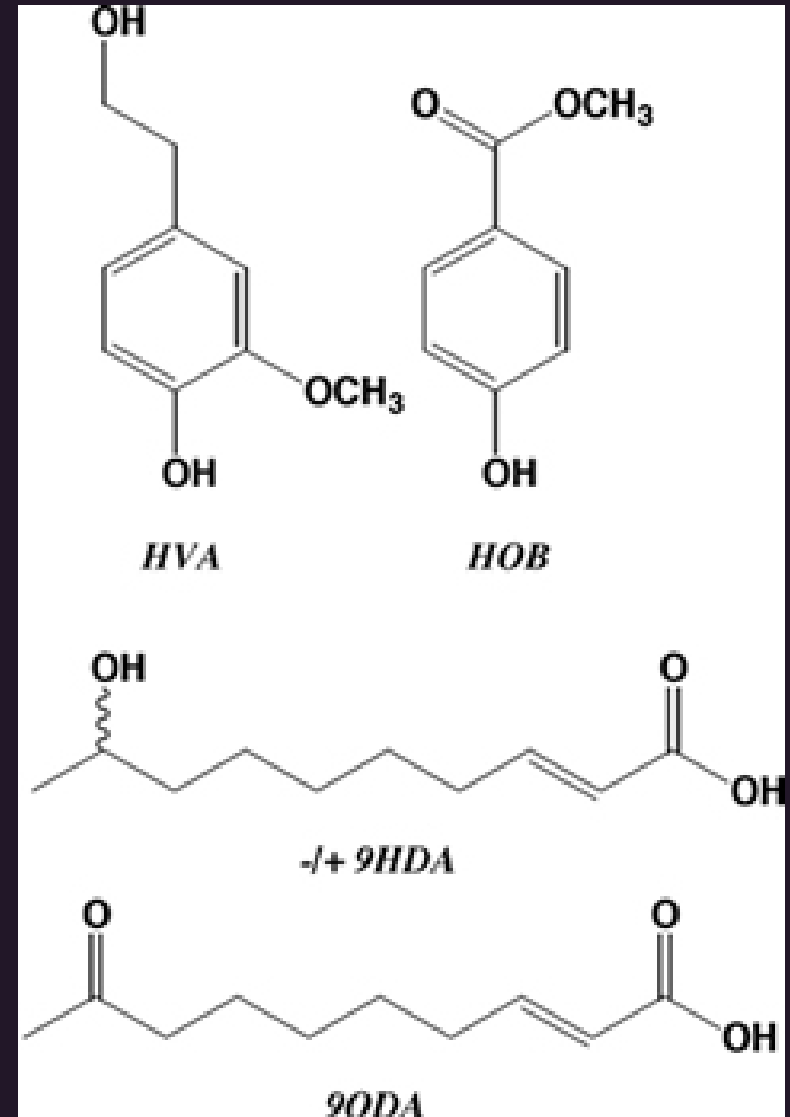
- If properly mated, a queen lays 1,500-2,000 eggs daily
- She is larger than workers, and her abdomen is elongated because she carries millions of eggs in her ovaries, and millions of sperm in the spermatheca



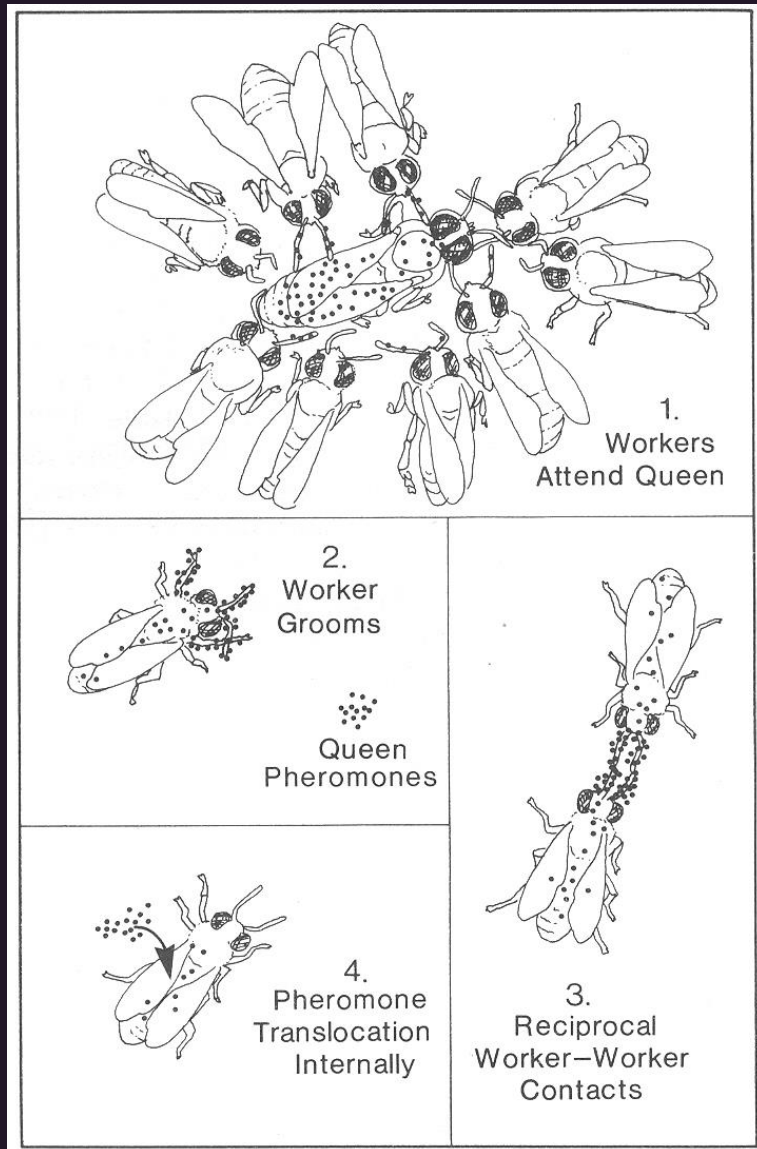
- A “queenright” colony functions as a cohesive unit largely in part because of the queen mandibular pheromones (QMP), which are transmitted around the colony through queen-worker contact

Queen Mandibular Pheromone (QMP)

- A blend of at least five different chemicals (9-ODA, 9-HDA, HOB, HVA)
- Produced by the queen's mandibular glands and spread all over her body
- Causes behavioral and physiological changes of colony members



Transmission of QMP around the colony

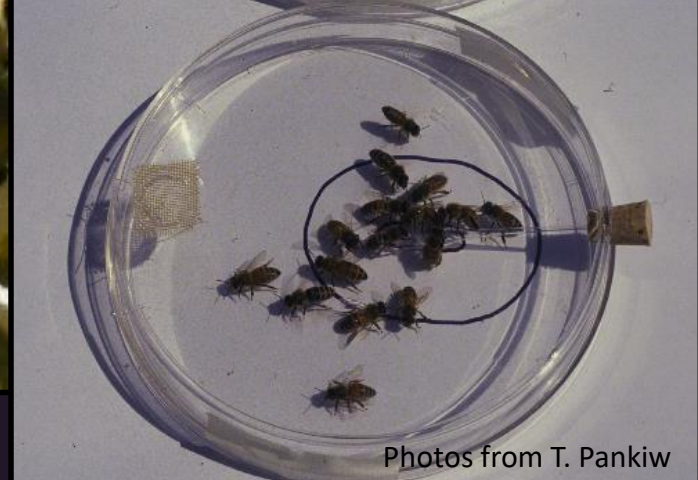


- Workers groom and lick the queen, picking up her pheromones
- Queen pheromones are further transmitted among all colony members by contact and trophallaxis

Elicits retinue response by workers

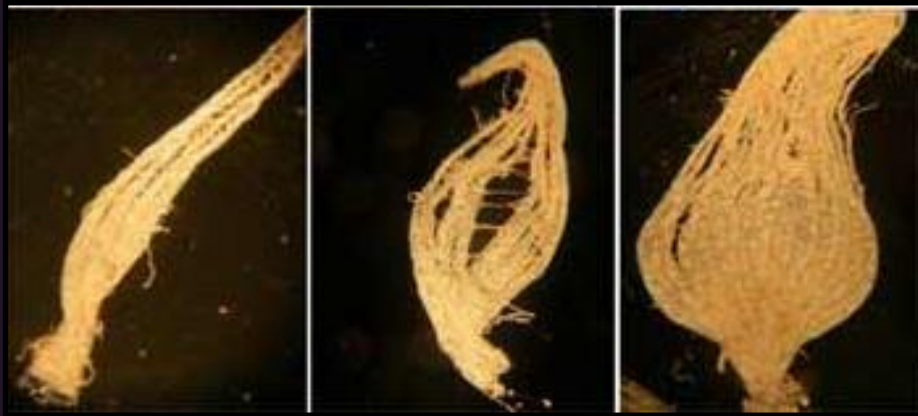


Photo from C. Grozinger

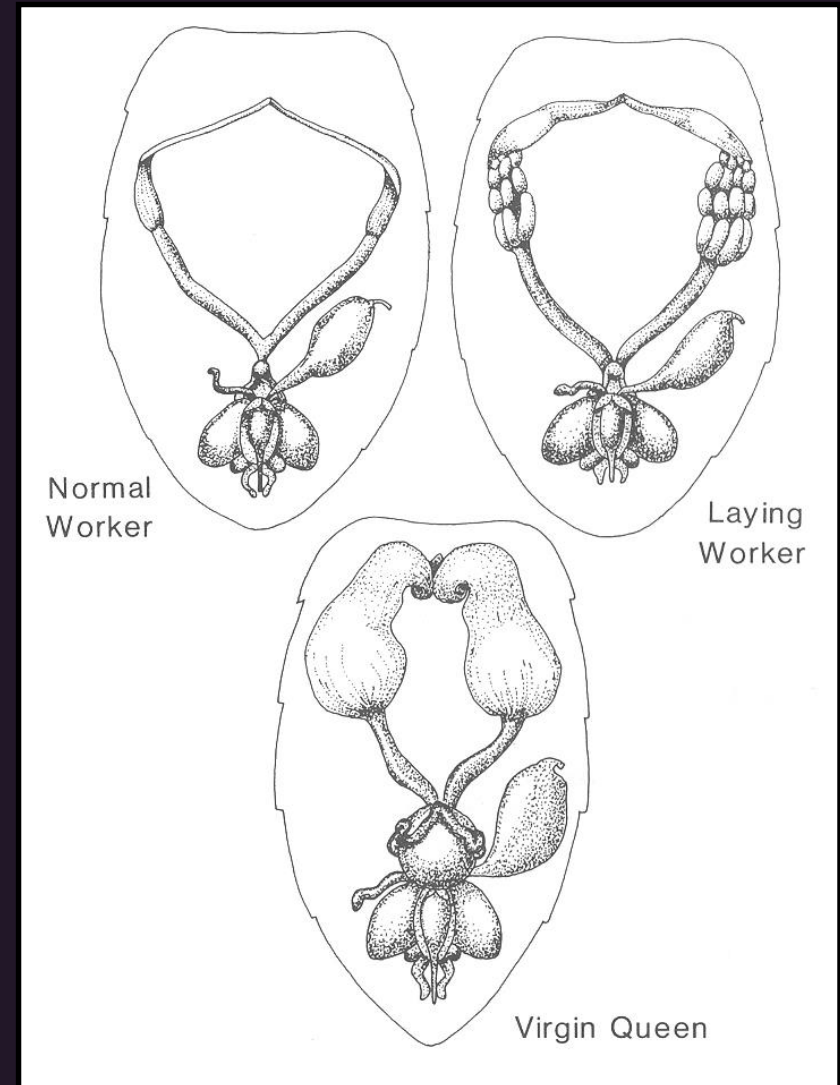


Photos from T. Pankiw

Inhibits worker ovary development



<http://www.journals.uchicago.edu>



Inhibits queen rearing by workers

The nest almost always has queen “cups” or starter cells to raise queens. In the presence of queen pheromone, they remain unoccupied...

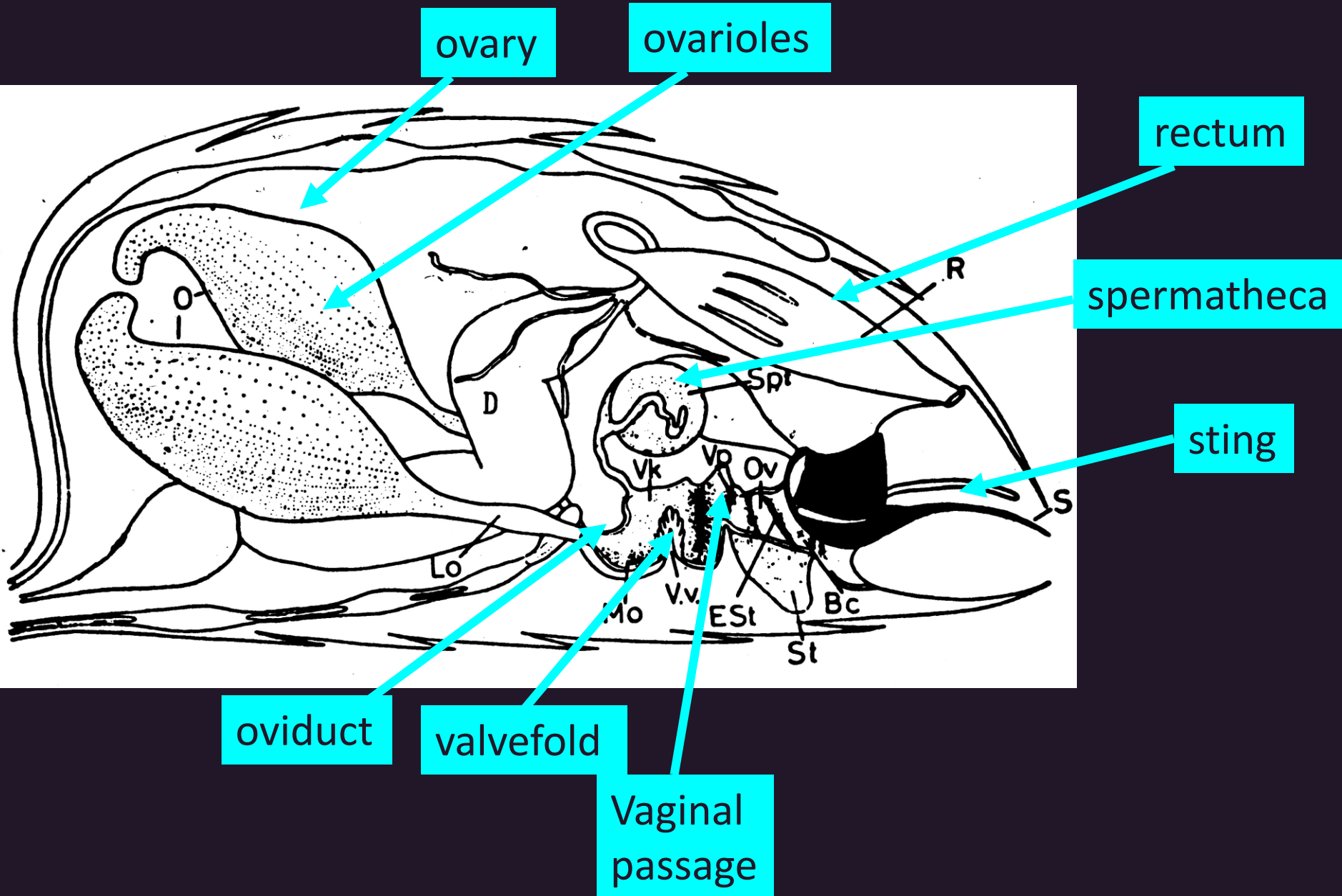


<http://www.birdchick.com/labels/bees.html>

...but in the absence of QMP, workers will raise several dozen queens in queen cells



Queen reproductive organs



Queen reproductive organs

Ovaries

- 2 lateral groups of ovarioles
- 150 ovarioles in each ovary
- Tubes converge at both ends
- Eggs travel down tubes and get fertilized one at a time

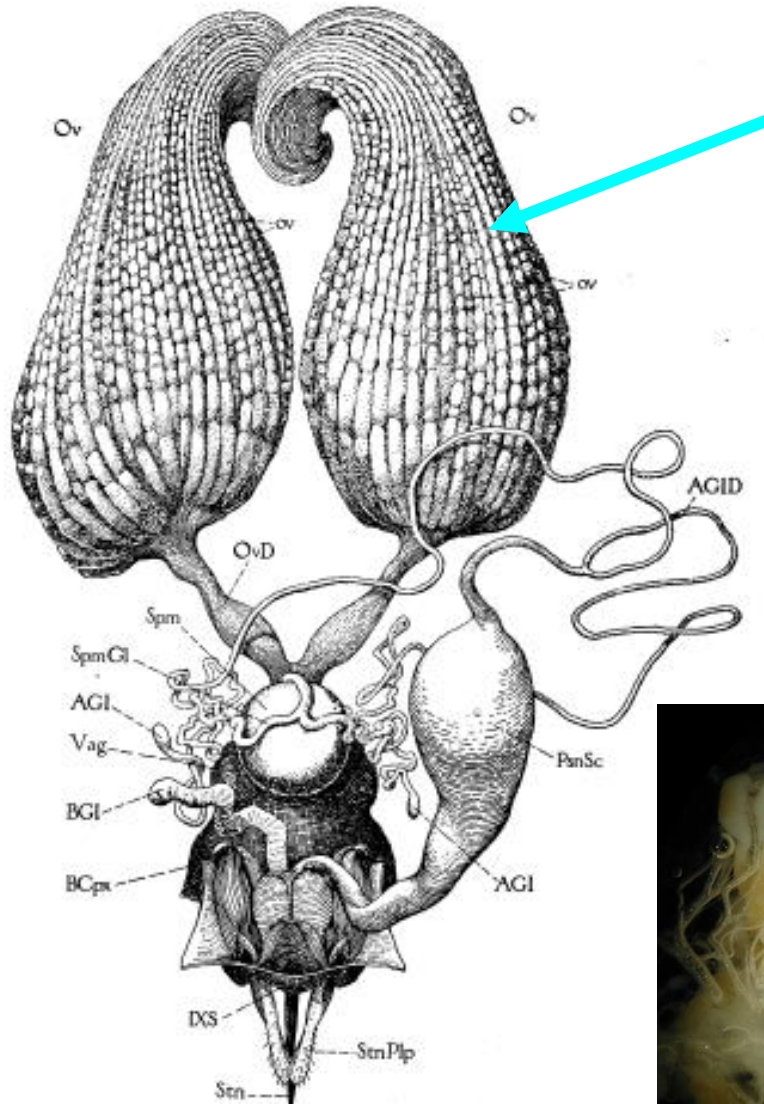
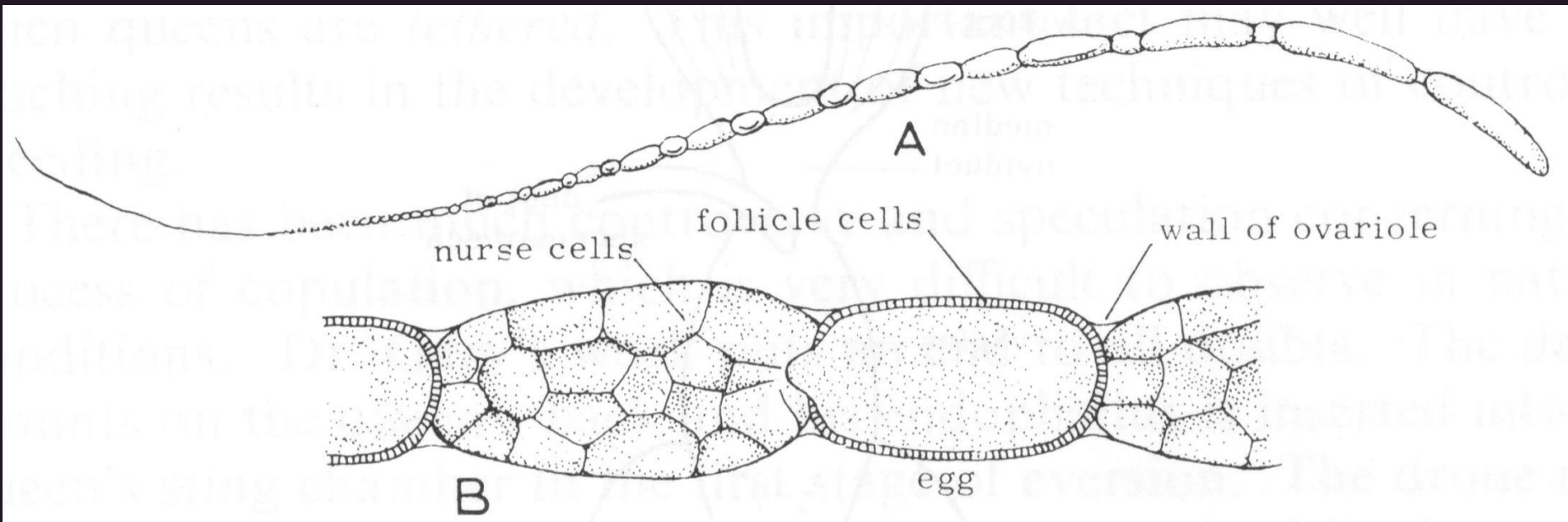


FIG. 57.—Reproductive organs, sting, and poison glands of queen, dorsal

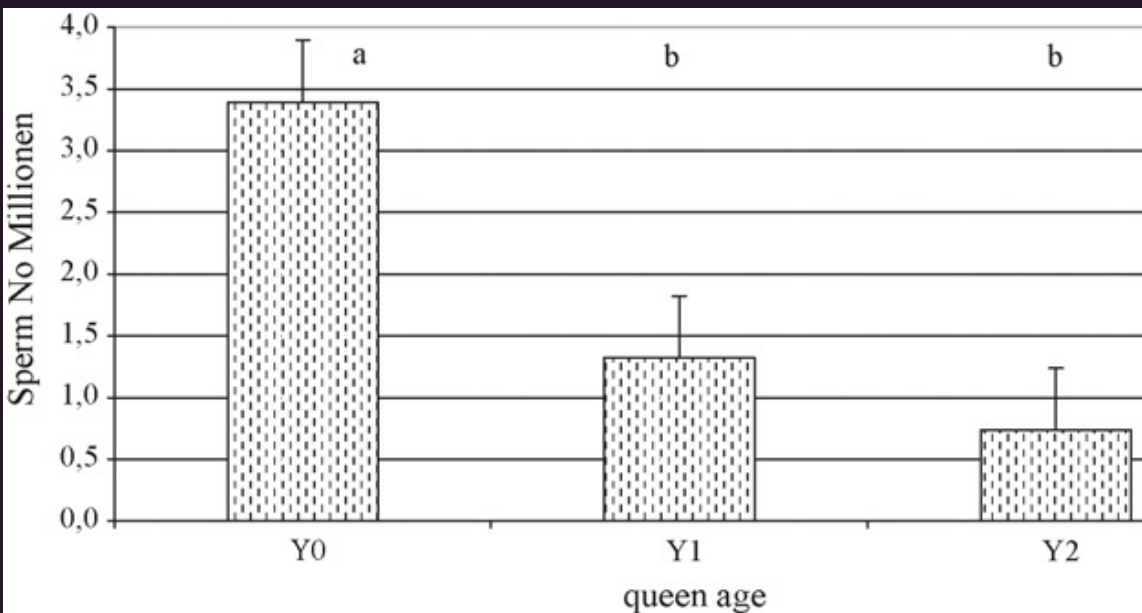


Egg production within the ovarioles

- Cells differentiate into nurse cells, follicle cells, and a developing egg
- 48 nurse cells per egg
- Egg matures as it travels toward oviduct
- Nurse cells eventually absorbed into yolk



Queen spermatheca

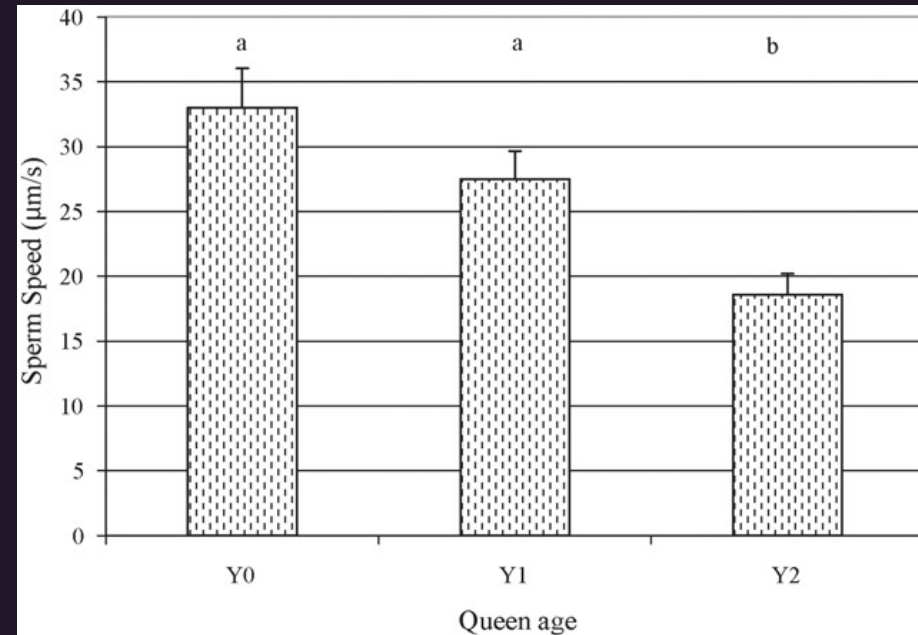


Al-Lawati et al. 2009

Spermatheca =
sperm storing organ
in queens



Sperm in mated queens



- Sperm in newly mated queens moves in circles and is faster than in old mated queens

Biology of drones



Drone development

- 24 days total from egg to drone emergence
- Day 24 – Emergence
- Day 36 – Sexual maturity
- Therefore, a minimum of 36 days are needed from the time drones are produced, to when they are ready to mate



Reaching sexual maturity

- All the sperm are formed before a drone's emergence from the cell, but the sperm needs to migrate into the seminal vesicles before the drone can mate (8-10 days post-emergence)
- A colony produces thousands of drones during the swarming season only if environmental conditions allow it, and if the colony is large

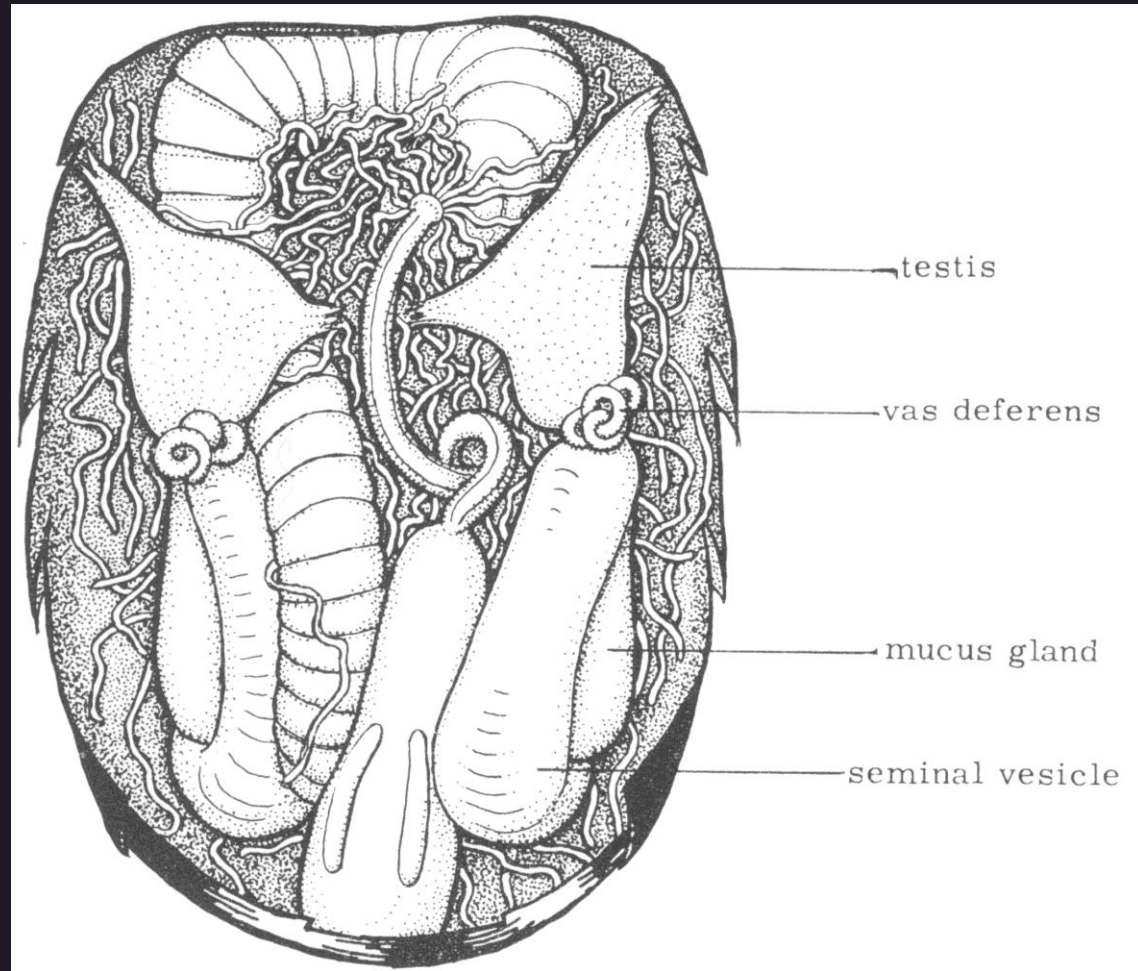
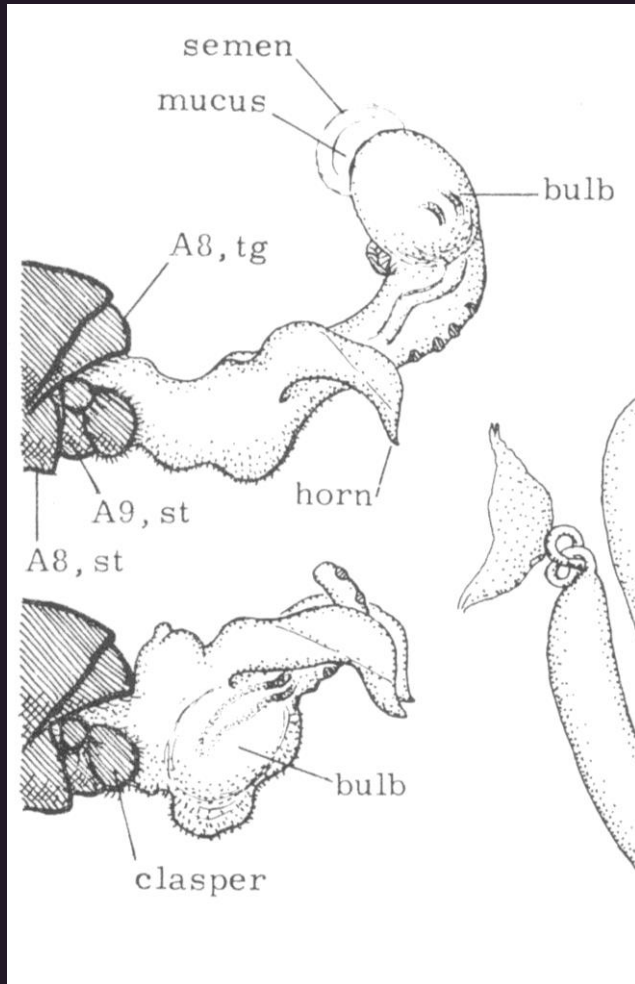


Drone development

- Young drones are fed in the brood nest. Once mature, they move from the center of the brood nest and congregate on the outer comb where nectar is stored
- Drones first leave the hive to take orientation flights about 8 days from emergence. They then leave the hive to mate every afternoon if the weather permits
- In fall, drones and brood are removed from the colony because they no longer serve a reproductive purpose. They die before winter

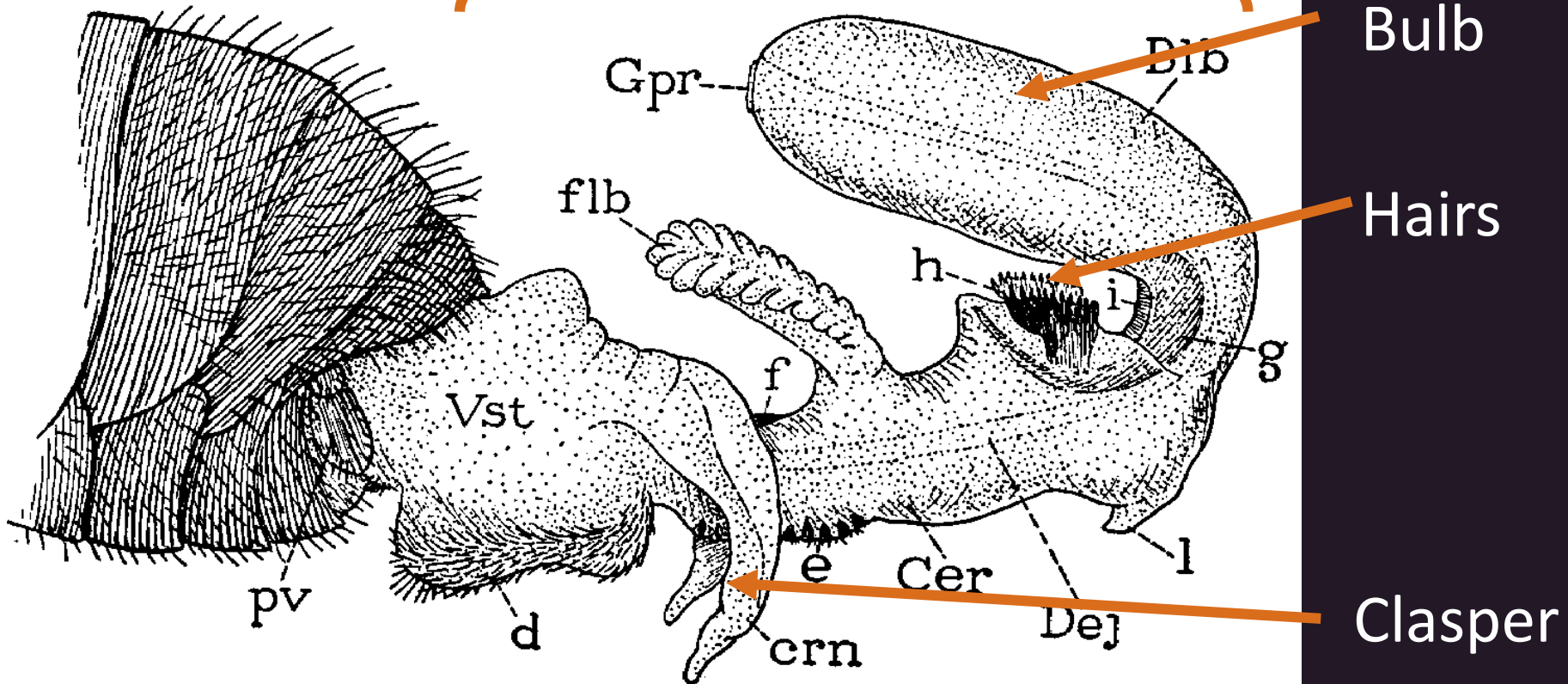


Drone reproductive morphology



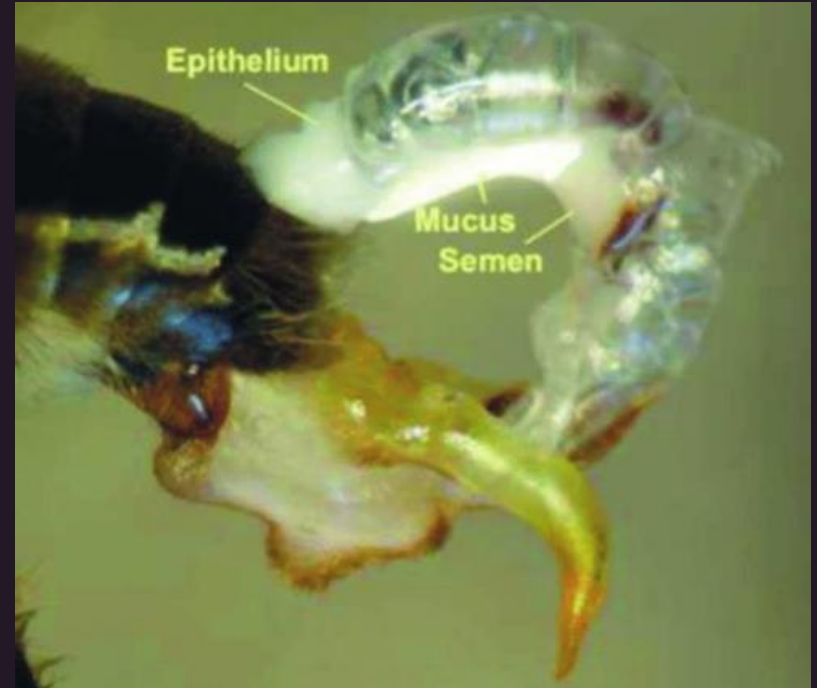
Drone reproductive organs

Endophallus



Sperm production in drones

- Mature drones have ≈ 10 million spermatozoa in their seminal vesicles, or about 0.5 mm^3 of semen
- But a drone provides <1 million spermatozoa to spermatheca
- A filled spermatheca contains $\approx 5+$ million spermatozoa and about $9\text{-}10 \text{ mm}^3$ sperm



Some “math” about drone production

- One full two-sided drone comb has $\approx 4,150$ drone cells
- One full drone comb produces $\approx 3,000$ drones
- On avg., ≈ 15 -20 drones for each virgin queen
- Thus, the drones from one comb of drone brood will supply sufficient mates for ≈ 175 virgin queens

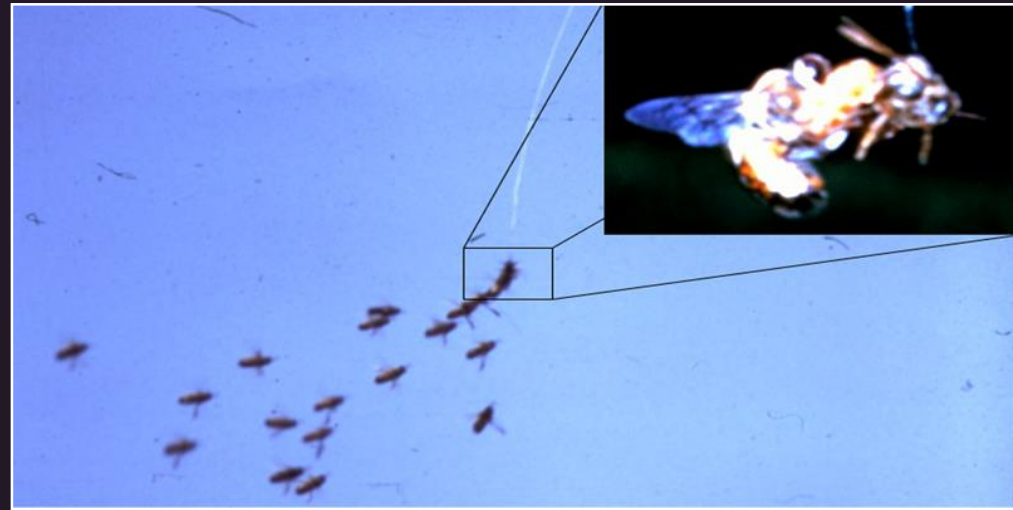




Biology of mating

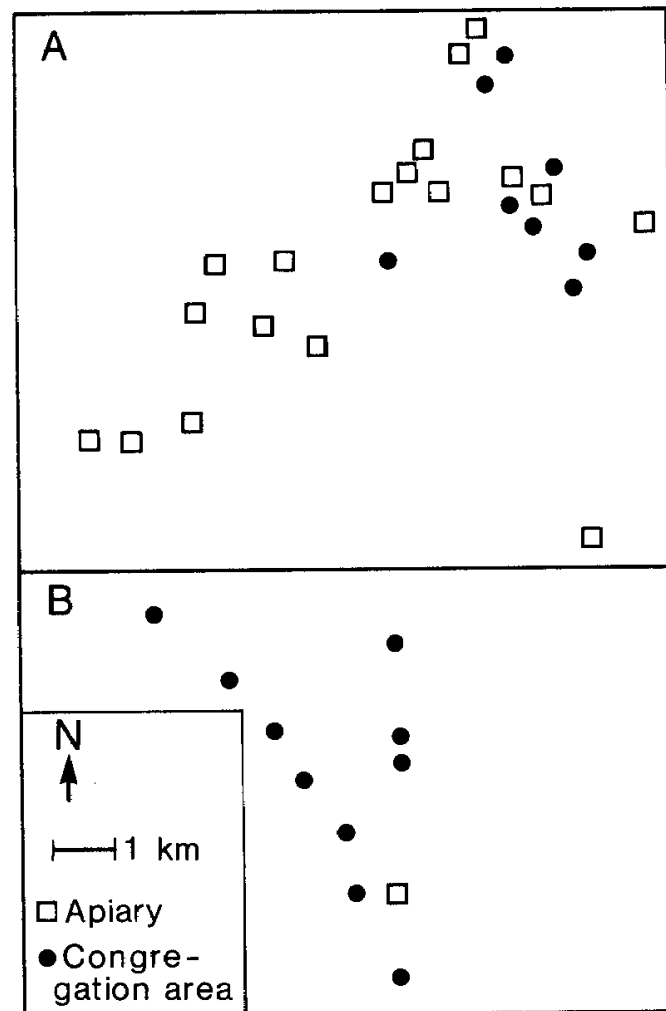
Drone Congregation Areas (DCAs)

- The queen leaves the hive and flies to Drone Congregation Areas (DCAs) where thousands of drones from nearby colonies await for a chance to mate
- DCAs are located within 1.5 Km from hive
- Up to 10,000 drones gather 10-40 m above ground
- Drones in DCAs represent any # of nearby colonies
- The day after a spell of bad weather in a colony with virgin queens 6+ days old, you will notice the disappearance of all the mature drones in your yard



Drone Congregation Areas (DCAs)

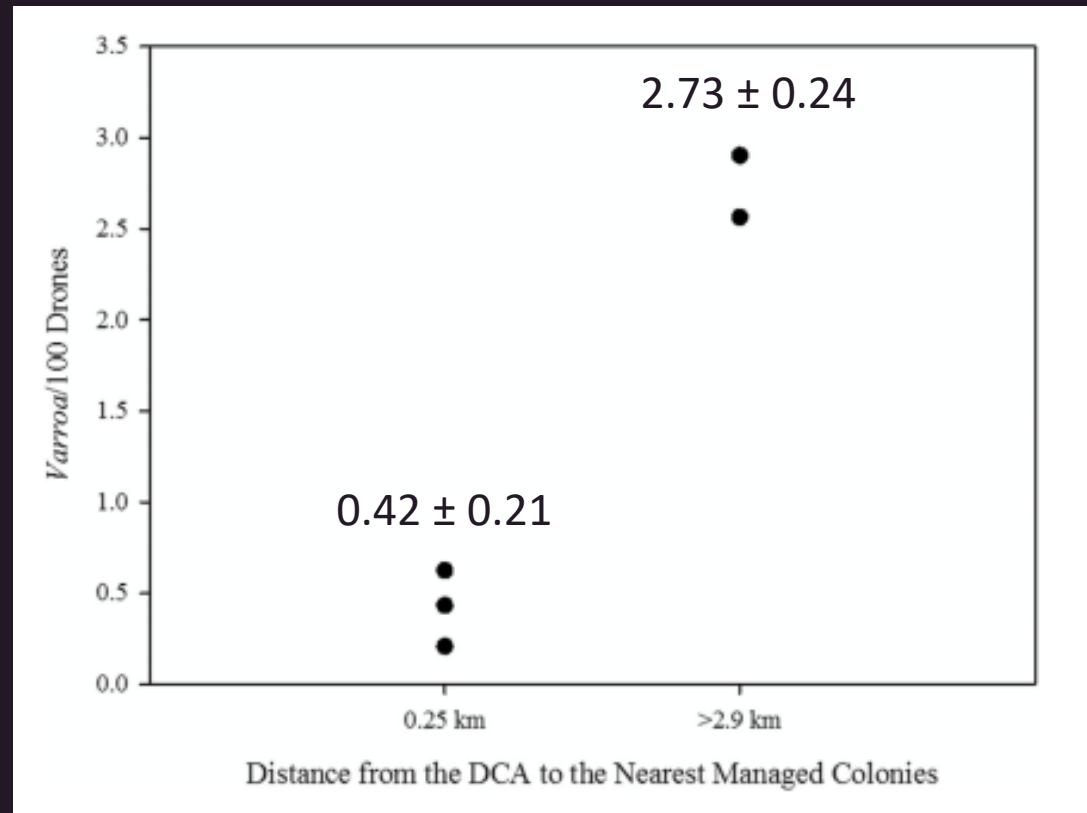
- *Very* stable, both spatially and temporally
- Follow geographic contours of the landscape
- But no general rules about where they are formed



The location of congregation areas relative to apiaries in two different areas:
(a) derived from data in Ruttner and Ruttner (1966) for a region in Austria;
(b) derived from Zmarlicki and Morse (1963) for New York State.

Varroa mites on drones at DCAs!!

- *Varroa*/100 drones based on the proximity of the DCA to managed EHB apiaries
- *Varroa* abundance highest at DCAs further from managed apiaries
- 349 drones analyzed from DCAs far from apiaries and 2983 drones analyzed from DCAs near a apiaries



Mortesen et al. 2018. The discovery of *Varroa destructor* on drone honey bees, *Apis mellifera*, at drone congregation areas. *Parasitology Research* 117:3337–3339

DCA distance to managed apiaries matters

Table 2. Mitochondrial DNA results for drones trapped at DCAs within 0.25 km of managed colonies of European honey bees or > 2.8 km from any managed colonies, and proportions of African and European matriline drones present at each DCA location type.

DCA locations	total no. drones analyzed	no. drones with European mtDNA	no. drones with African mtDNA	% of drones with European mtDNA	% of drones with African mtDNA
0.25 km from apiary	400	399	1	99.75%	0.25%
	400	397	3	99.25%	0.75%
	400	382	18	95.50%	4.50%
>2.8 km from apiary	400	231	169	57.75%	42.25%
	400	291	109	72.75%	27.25%
	400	266	134	66.50%	33.50%

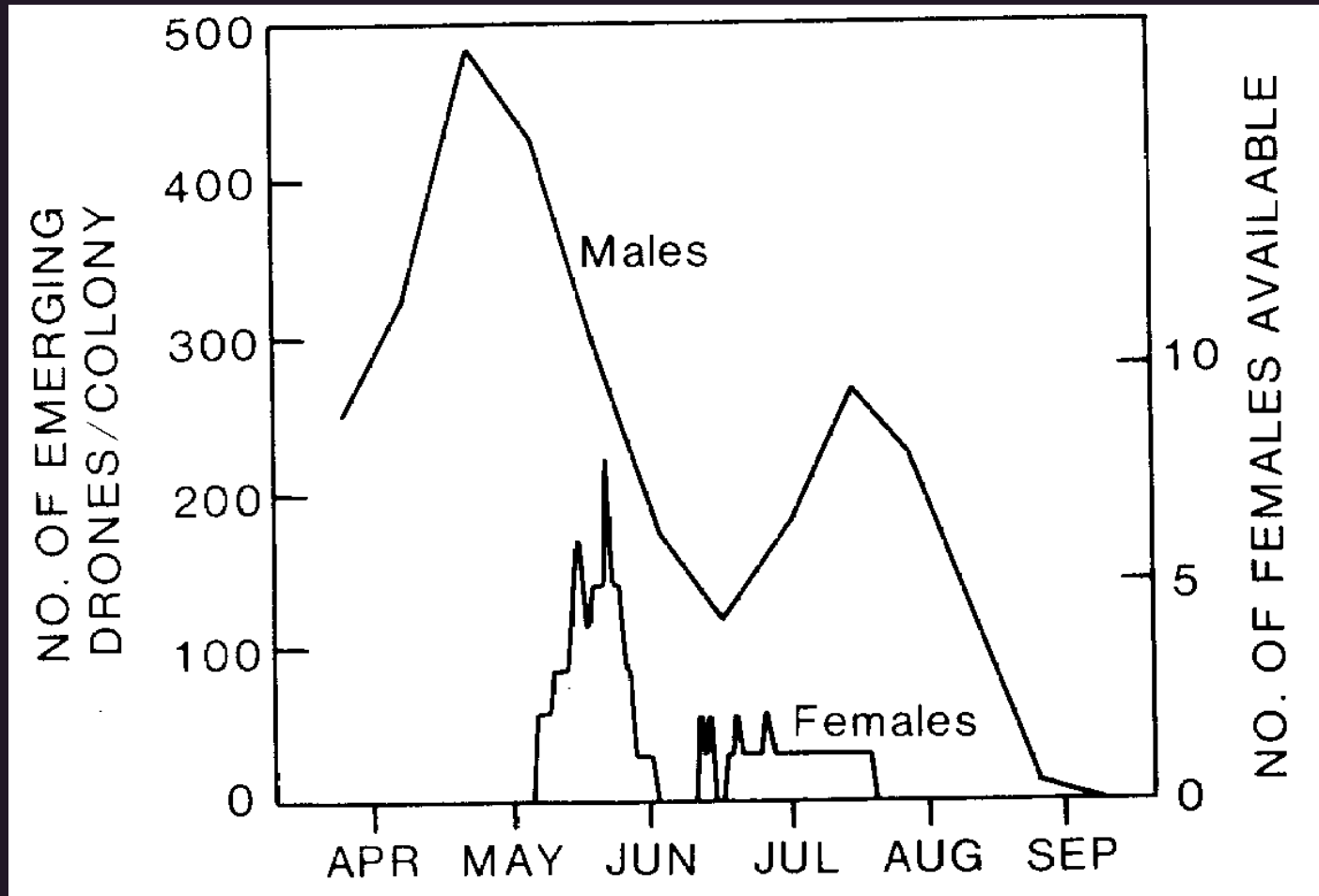
Note: The total proportion of drones with African (and correspondingly European) mtDNA was significantly different ($\chi^2_{1, 2400} = 427.83, p < 0.0001$) between DCAs near (0.25 km, 1.8% of drones had African mtDNA) and far (>2.8 km, 34.3% of drones had African mtDNA) from managed European honey bee colonies based on Pearson's χ^2 test.

doi:10.1371/journal.pone.0161331.t002

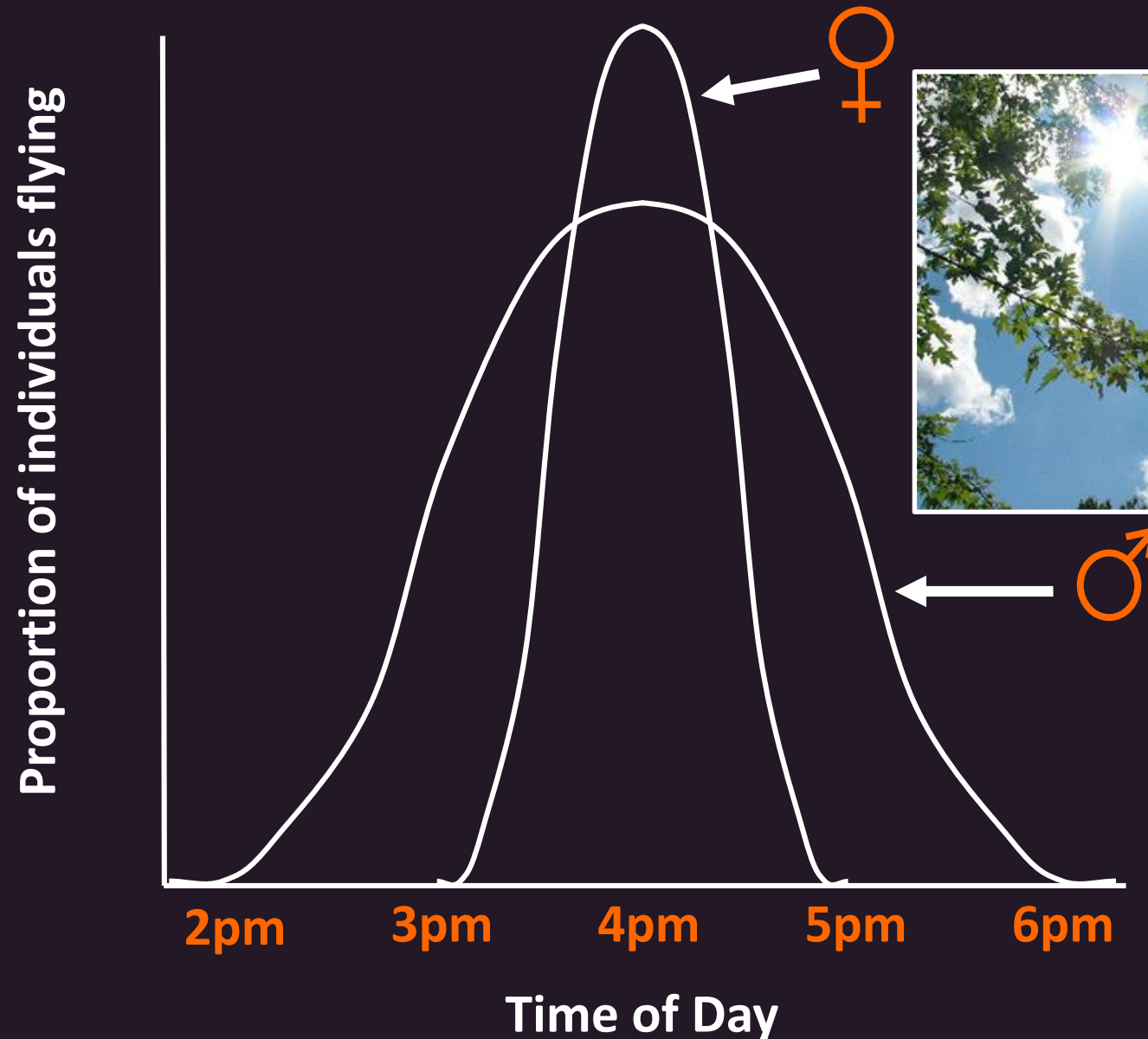
- DCAs far from managed European honey bee apiaries (> 2.8 km) had significantly more African matriline drones (34.33%) than did DCAs located close to managed EHB apiaries (1.83%)
- No effect of height of DCA on matrilineal composition

Seasonal distribution of queens and drones

- Temporally, drones emerge earlier than queens and wait around until later in the DCAs for the queens to arrive

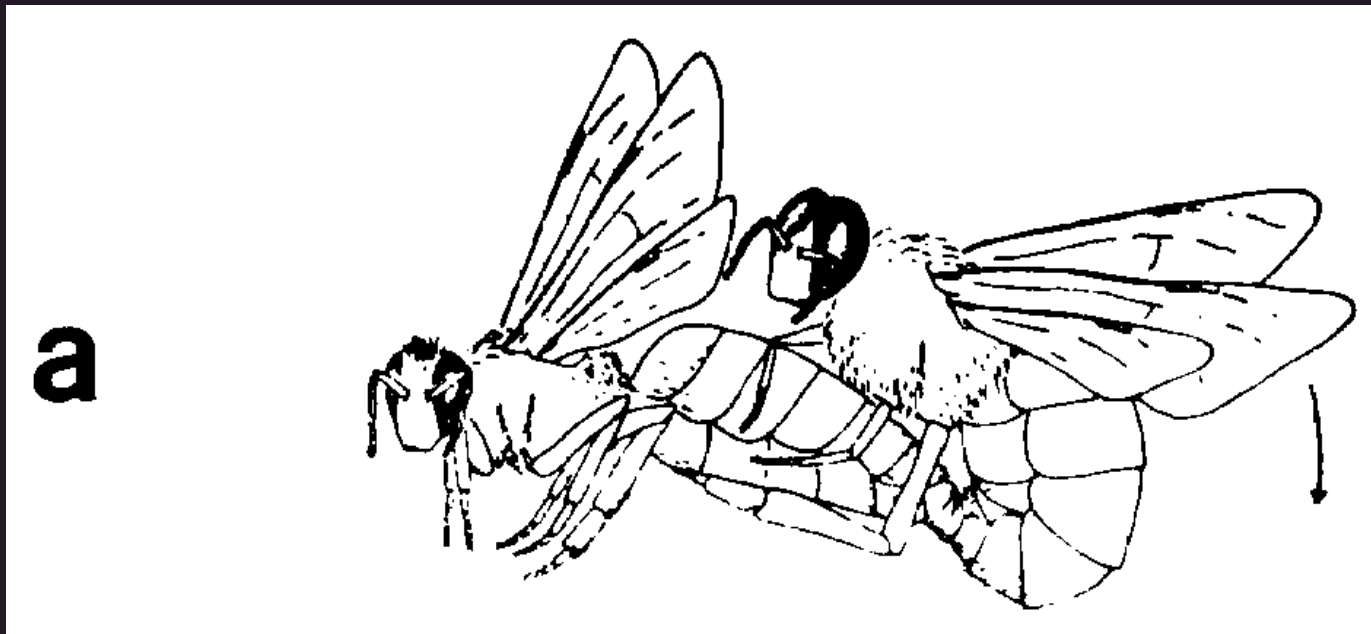


Daily activity of queens and drones



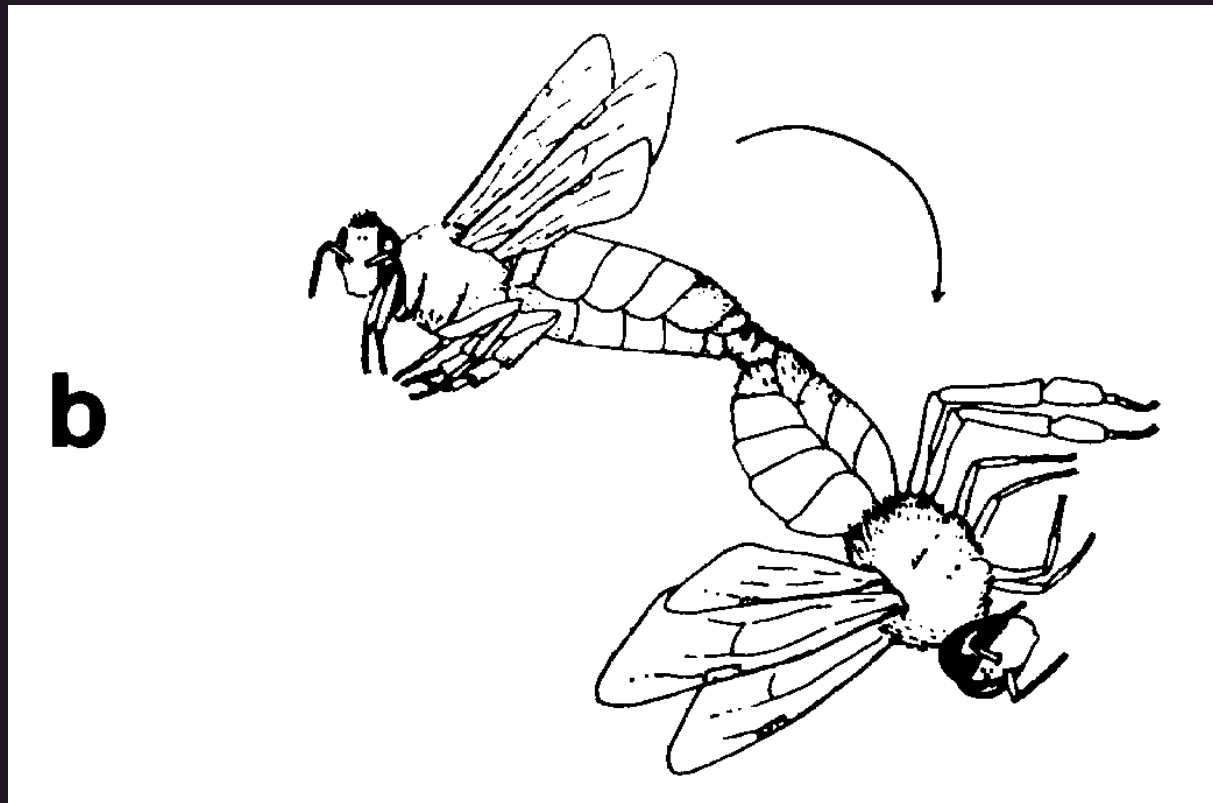
Copulation: Step by step

- The drone mounts the queen from behind and grabs her with the claspers, his abdomen is curved inward, and the endophallus is everted and inserted into the queen's reproductive tract



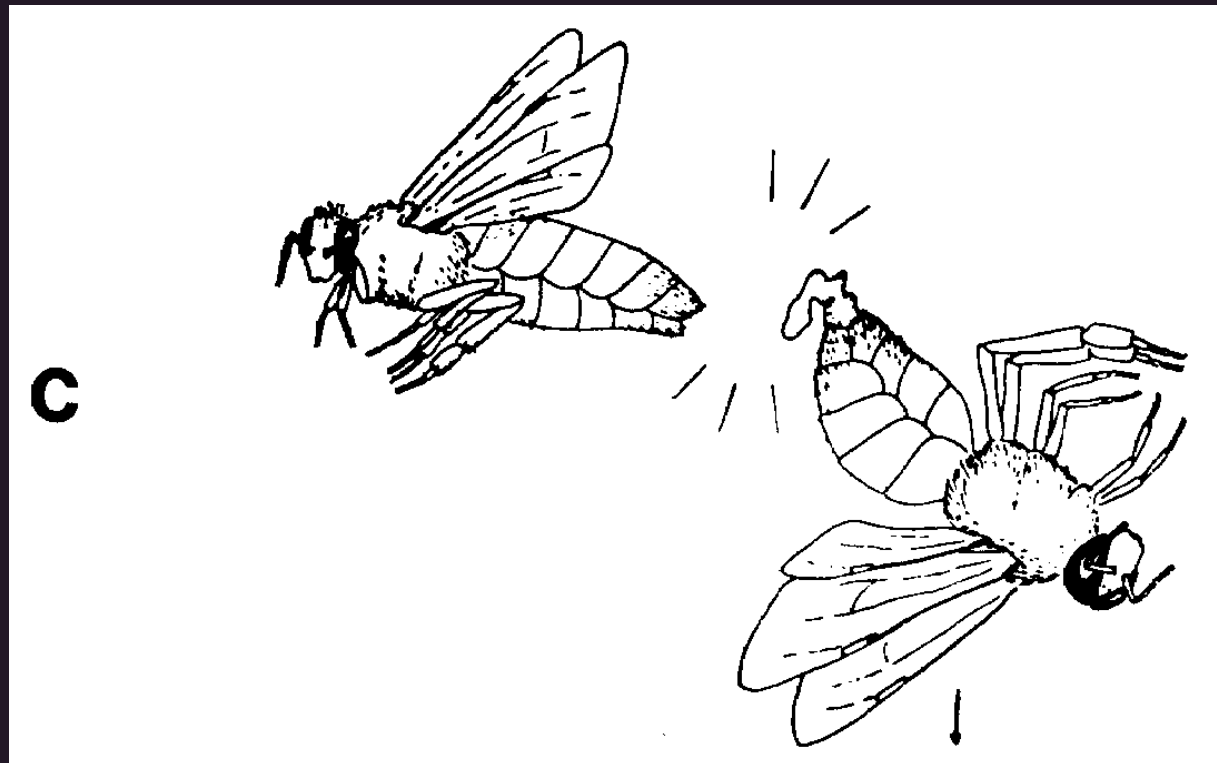
Copulation: Step by step

- The drone lets go of the queen, but the eversion of the endophallus ruptures the drone's reproductive tract



Copulation: Step by step

- Once copulation is over, the end of the endophallus (“bulb”) breaks off within the queen and remains within the sting chamber, leaving a visible “mating sign” as the dying drone drops away



Copulation: Step by step

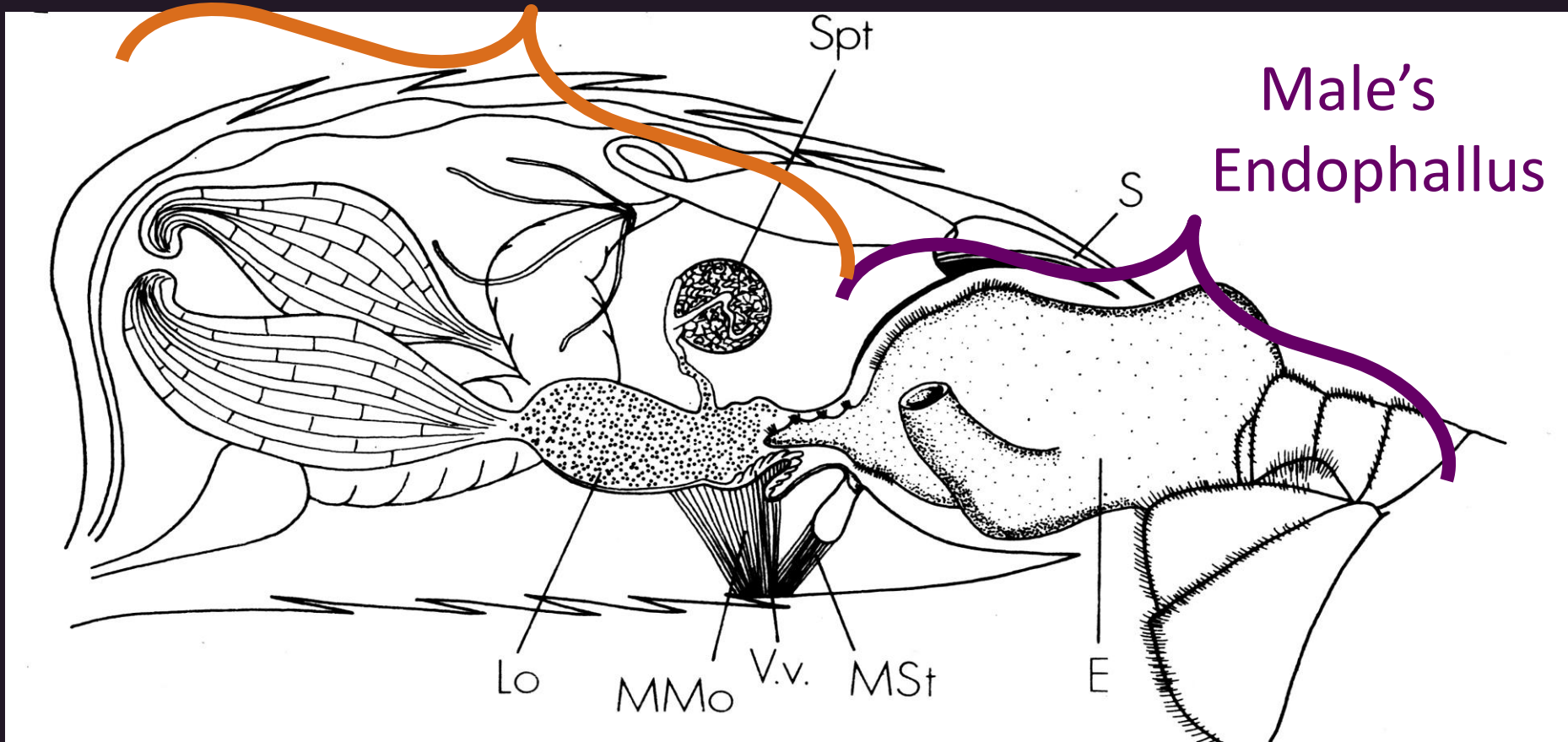


Copulation: Step by step



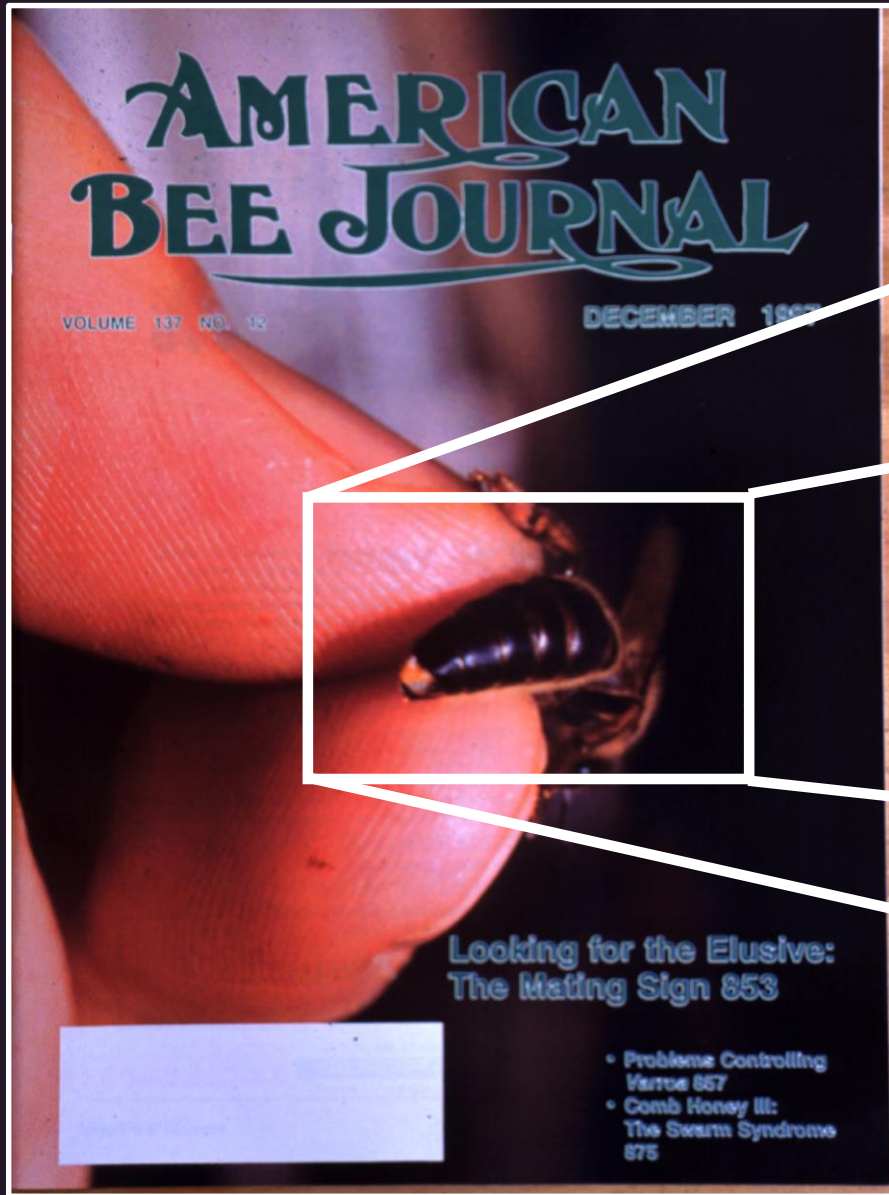
Copulation: Step by step

Queen's reproductive tract



- Subsequent drones who mate with queen dislodge the mating sign left by the previous drone.

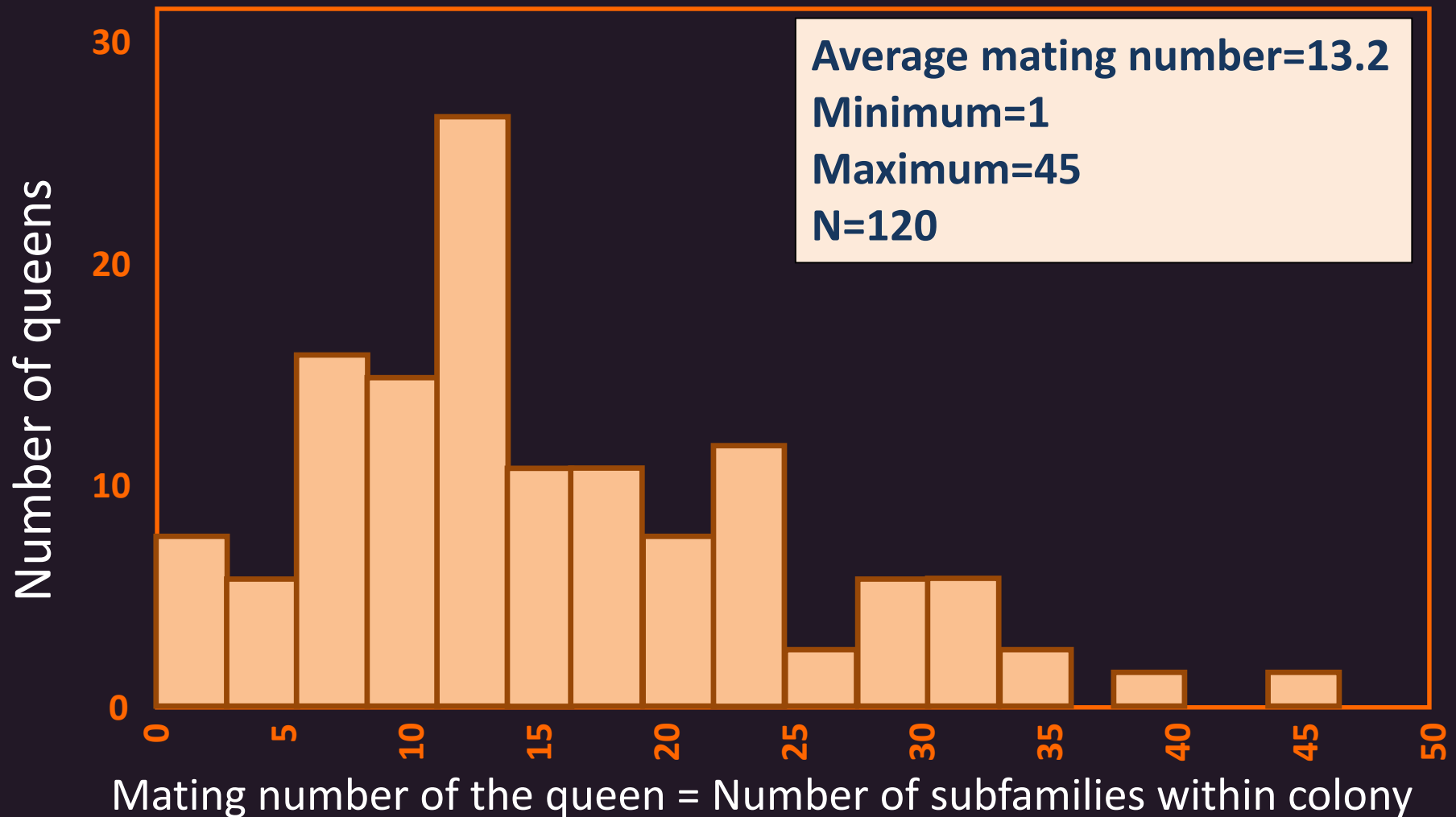
“Mating sign” upon copulation



- The workers remove the last mating sign from the queen in the hive

Multiple mating by the queen: Polyandry

Although queens in most social insects mate only once, honey bee queen mate multiply for many reasons



Take home messages

- Beekeepers need to understand the biology of queens and drones, as well as the colony cycles in order to manipulate colonies to our advantage
- Carefully time when queens will mate (swarming mode) to the time when drones are mature. Remember that you need at least 32 days from egg to sexual maturity for drones to be able to mate with queens during the swarming season
- Good record keeping is essential for successful queen rearing. Queens should be marked so that you know whether your colony has the original queen or if it may have swarmed recently

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The Texas A&M University Honey Bee Research Program, led by Dr. Juliana Rangel, Associate Professor of Apiculture in the Department of Entomology, focuses on basic and applied research, as well as education and outreach regarding honey bee biology and management. Our research interests revolve around the reproductive biology of honey bee queens and drones, the behavioral ecology and population genetics of feral and managed honey bee colonies, as well as pollination and beekeeping practices.

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Latest News:

5th Annual “*ART OF QUEEN REARING*” Workshop Saturday, 18 May 2019

Janice and John G. Thomas Honey Bee Facility, College Station, TX Head Instructor: Dr. Juliana Rangel

Special Guest: Sue Cobey


Co-Instructors: ET Ash, Pierre Lau, Alex Payne, Liz Walsh, Taylor Reams








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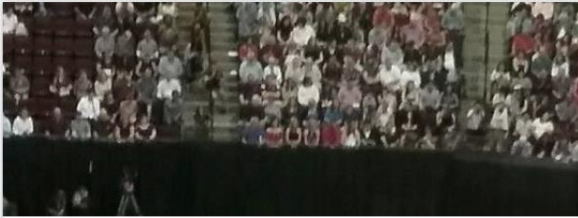
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